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Updated information on the TeraHertz transistor is available in the 90nm process documents on <http://proto-cps.jf.intel.com/research/silicon/micron.htm>



BACKGROUND

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INTEL'S TERAHERTZ TRANSISTOR ARCHITECTURE

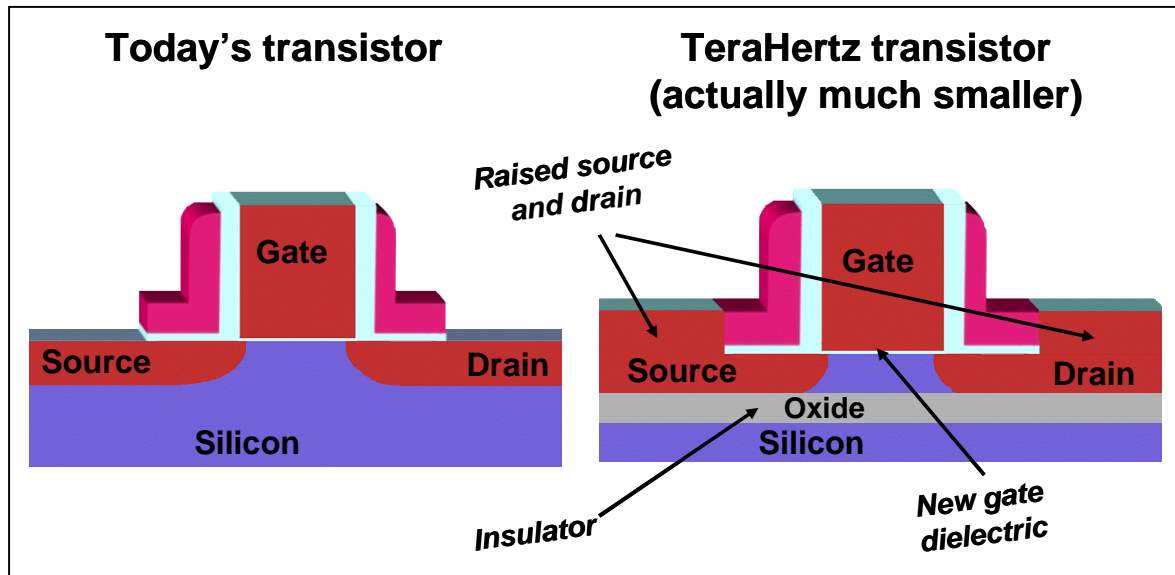
Intel's researchers have developed a new type of transistor that it plans to use to make microprocessors and other logic products (such as chip sets) in the second half of the decade. The so-called "TeraHertz" transistors will allow the continuation of Moore's Law, with the number of transistors doubling every two years, each one capable of running at multi-TeraHertz speeds, by solving the power consumption issue.

Intel has shown that it can scale transistors from 30nm (December 2000) to 20nm (June 2001), and to 15nm (November 2001). A transistor that scales by 30% in one dimension is reduced in area by 50%, thus doubling the number of transistors, thereby delivering more value to the end user by delivering applications that were previously not possible. It is also able to switch much faster. A TeraHertz transistor is able to switch between its "on" and "off" state over 1,000,000,000,000 times per second (equal to 1000 GigaHertz.).

The key problem solved by the TeraHertz transistor is that of power. As more and more transistors are packed onto a sliver of silicon, and they are run at higher and higher speeds, the total amount of power consumed by chips is getting out of hand. Chips that draw too much power get too hot, drain batteries unnecessarily (in mobile applications) and consume too much electricity. The latter is a particular problem in servers. If this power problem is not addressed, Moore's Law will be throttled and futuristic applications

such as real-time speech recognition and translation, real-time facial recognition (for security applications) or rendered graphics with the qualities of video will never be realized. These types of applications will require microprocessors with far more transistors than today, and running at much higher speeds than today.

A New Type of Transistor



As can be seen in the left half of the illustration, the basic transistor in use today has 3 terminals: gate, source and drain. The transistor is an on/off switch. Electricity flows from source to drain if the gate is on; it does not flow if the gate is off (the gate's state is determined by its voltage). The transistor is built on a wafer of silicon. The source and drain are variants of the basic silicon and the gate is a material called polysilicon. Below the gate is a thin layer called the gate dielectric. It is made of silicon dioxide today. All CMOS circuits today are made of transistors such as this, hooked up to each other by interconnects (wires). The Pentium® 4 processor has 42 million such transistors on a fingernail-sized piece of silicon.

As mentioned previously, simply making these transistors smaller and faster is not feasible due to the power problem. Intel's new TeraHertz transistor allows for scaling, and addresses the power problem. The goal with the TeraHertz transistor is that microprocessors will consume no more power than today, even though they will consist

of many more transistors. The TeraHertz transistor has 3 new features, as shown on the right of the illustration: a new gate dielectric, a layer of oxide buried within the silicon, and raised source and drain. These 3 features solve the power problem as follows:

Source of power problem	Why it is a problem?	Solution (see illustration above)	Why this solves the problem
1. Unwanted current flow across gate dielectric	As gate dielectrics get ever thinner, current leaks through, even though the dielectric is an insulator	Replace silicon dioxide with a new material with a “high k” value	New material has same desired electrical properties but is physically thicker, hence reduces leakage by 10,000X
2. Unwanted current flow from source to drain when transistor is “off”	As transistors get smaller, current flows between the source and drain even when it shouldn’t	Insert a layer of insulator (oxide) under the transistor	The oxide layer blocks the path of this unwanted current flow, reducing it by 100X
3. High voltage needed, thereby increasing power usage	Addition of the oxide layer to fix problem 2 increases resistance in the source and drain	Make the source and drain thicker	Thicker source and drain reduce resistance by 30%, giving the electrons more mobility so less voltage is required

In addition to solving these 3 problems, the TeraHertz transistor has 3 other beneficial features:

Feature	Why it is a problem?	Solution with TeraHertz Transistor	Benefit
1. Low junction capacitance	Electrical effect at the periphery of the source or drain which slows down electrons	Source and drain abut buried oxide layer	Allows transistor to run faster
2. Alpha particle immunity	Stray radioactive particles arrive from atmosphere or package which can lodge under transistor and affect its behavior	Region above buried oxide layer is very thin, leaving almost no space for alpha particles	Increased reliability

Feature	Why it is a problem?	Solution with TeraHertz Transistor	Benefit
3. No “floating body” effect	Charge can get trapped between the gate dielectric and the buried oxide layer, affecting behavior of the transistor	Region above buried oxide layer is very thin and cannot collect charge during transistor operation	Ease of circuit design

An Exciting New Technology

Intel is very excited about having developed the TeraHertz transistor. By addressing the power problem, it paves the way for the continuation of Moore’s Law through the end of the decade, and this will enable end user applications that are beyond our imagination today.

As with any new technology, there are numerous technical issues that need to be resolved before volume production can begin. Intel believes that the TeraHertz transistor architecture will become the clear choice for the second half of the decade.

For more details about Intel’s TeraHertz Transistor architecture and other Intel research developments, visit www.intel.com/research/silicon.